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FINAL WORK PLAN FOR BASELINE ECOLOGICAL RISK ASSESSMENT LAB AREA NSWC INDIAN HEAD MD

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CH2MHILL

Final

Work Plan for Baseline Ecological Risk Assessment Lab Area

Naval District Washington, Indian Head
Indian Head, Maryland

NAVFAC
Naval Facilities Engineering Command

Prepared for

Department of the Navy
Naval Facilities Engineering Command Atlantic

Contract No. N62470-02-D-3052
CTO-0043

March 2005

Prepared by

CH2MHILL

Final

Work Plan
Baseline Ecological Risk Assessment
Lab Area

Naval District Washington, Indian Head
Indian Head, Maryland

Contract Task Order 043

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Prepared for

Department of the Navy
Naval Facilities Engineering Command Washington

Under the

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Prepared by

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Herndon, Virginia

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Acronyms and Abbreviations

B&RE	Brown & Root Environmental
BERA	Baseline Ecological Risk Assessment
BTAG	Biological Technical Assistance Group
CLEAN	Comprehensive Long-Term Environmental Action Navy
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CTO	Contract Task Order
DQO	data quality objective
EC_{10}	Effects Concentration 10 percent
EC_{50}	Effects Concentration 50 percent
E/A&H	Ensafe/Allen & Hoshall
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
HQ	hazard quotient
IDWD	Investigation-derived waste
IHDIV-NSWC	Indian Head Division—Naval Surface Warfare Center
IR	Installation Restoration (program)
LC_{50}	Lethal Concentration 50 percent
LOAEL	Lowest Observed Adverse Effect Level
MDE	Maryland Department of the Environment
□g/kg	micrograms per kilogram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MS/MSD	Matrix Spike and Matrix Spike Duplicate
NAVFAC	Naval Facilities Engineering Command
NDW	Naval District Washington
NDWIH	Naval District Washington, Indian Head
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
PAH	polynuclear aromatic hydrocarbon
ppm	parts per million
QAPP	Quality Assurance Project Plan
QC	quality control
RI	Remedial Investigation

SERA	Screening Ecological Risk Assessment
SIM	selective ion monitoring
SOP	standard operating procedure
SVOC	semivolatile organic compound
TAL	Target Analyte List
TCL	Target Compound List
TOC	total organic carbon
VOC	volatile organic compound

SECTION 1

Introduction

This Baseline Ecological Risk Assessment (BERA) Work Plan for the Lab Area [i.e., Installation Restoration (IR) Program Sites 14, 15, 16, 49, 50, 53, 54, and 55], located at the Naval District Washington, Indian Head (NDWIH)[1] installation in Indian Head, Maryland, was prepared for Naval Facilities Engineering Command (NAVFAC) Washington in response to Contract Task Order (CTO) 043 under the Comprehensive Long-Term Environmental Action Navy (CLEAN) contract number N62470-02-D-3052 (i.e., CLEAN III). This Work Plan addresses all work activities required to conduct the BERA at the Lab Area.

1.1 BERA Objectives

The objectives for the BERA at the Lab Area are the following:

- Provide a detailed assessment of exposure and hazard to assessment endpoints (i.e., ecological qualities to be protected);
- Refine the problem formulation developed for the Screening Ecological Risk Assessment (SERA);
- Develop the study design, defining measurement endpoints and Data Quality Objectives (DQOs);
- Collect additional samples and data to support the detailed assessment; and
- Develop site-specific values that are protective of the environment.

1.2 Document Organization

The BERA Work Plan is organized as follows:

- Section 1 presents the objectives of the BERA, the Work Plan document organization, and the BERA project organization.
- Section 2 presents a general description of the facility and the site, a summary of the site history, and a description of previous ecological risk assessment work at the site.
- Section 3 presents Step 3B of the ecological risk assessment process (the refined problem formulation).
- Section 4 presents the Study Design and Data Quality Objectives for the BERA.
- Section 5 presents a description of the field investigation program.

[1] On October 1, 2003, the installation management functions at Indian Head transferred from the Indian Head Division, Naval Surface Warfare Center (IHDIV-NSWC) to Naval District Washington (NDW). This installation will now be referred to as NDW, Indian Head (NDWIH).

Tables are included in the main text and figures are provided at the end of each section.

1.3 Project Organization

CH2M HILL will conduct this BERA with support from the Navy. The Navy Remedial Project Manager will be Mr. Joseph Rail:

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SECTION 2

Site Background

NDWIH is a Navy facility in northwestern Charles County, Maryland. The facility provides services, research, development, testing, and evaluation in energetics [Brown & Root Environmental (B&RE), 1997a]. The facility consists of a main area, located on Cornwallis Neck Peninsula, and the Stump Neck Annex, located across Mattawoman Creek from the main facility area. The main area is bounded by the Potomac River to the northwest, west, and south; Mattawoman Creek to the south and east; and the town of Indian Head to the northeast.

The specific IR Program sites covered in this Work Plan are NDWIH Sites 14, 15, 16, 49, 50, 53, 54, and 55. As a result of similar historic usage, proximity, the sharing of sewer utilities, and overlapping field investigations, it was decided by the United States Navy (Navy), Maryland Department of the Environment (MDE), and United States Environmental Protection Agency (EPA) Region III in May 2000 to simply refer to the area encompassing Sites 14, 15, 16, 49, 50, 53, 54, and 55 as the "Lab Area." The Lab Area is located in the northeastern portion of NDWIH (refer to Figure 2-1).

The Lab Area consists of various office buildings, current and former laboratories, storage magazines, and other buildings and structures. Most of the structures in the Lab Area were used as laboratories or for chemical storage at one time in their history [refer to Section 1.4 of the Final Remedial Investigation (RI) Report for the Lab Area (CH2M HILL, 2004a) for more information]. Based on available information of historical practices, there are many possible chemicals of potential concern (COPCs) associated with the Lab Area, particularly mercury (refer to Section 1.4 of the Final RI). Because COPC contamination is associated with Lab Area structures, the site is likely delineated to the north by Evans Road, except for potential hot spots near Buildings 0600 and 0556 (the only areas north of Evans Road where structures are present).

2.1 Environmental Setting

The Lab Area covers approximately 14 acres. The majority of the area is maintained, containing grass and trees (oaks are common). A small emergent wetland (less than 0.5 acre) with cattails, rushes, and several trees receives runoff from the Lab Area, blow-off water from the steam system, and recharge from periodically broken water lines that run beneath the northern edge of the wetland (refer to Figure 2-2). Groundwater is more than 40 feet below ground surface throughout the site [Ensafe/Allen & Hoshall (E/A& H), 1994] and does not discharge to the wetland. Overflow from the wetland area drains into the storm drain system. The storm drain outlets to Mattawoman Creek near IR Program Site 41. As recommended in Section 7.2 of the Final RI Report, a soil/sediment removal action and restoration is planned for the wetland area after the BERA is completed for the upland portion of the Lab Area. The wetland restoration will be completed after the BERA to ensure that potential sources upgradient of the wetland are contained before restoration in order to minimize the potential for recontamination of the restored wetland. A literature-based

preliminary remedial goal (PRG) will be developed for the wetland sediment. Nature and extent and fate and transport information developed during the RI will be used in conjunction with the results of the BERA in order to select an appropriate remedy for the upland soil. The remedy will minimize the potential for recontamination of the wetland.

2.2 Previous Ecological Risk Assessment Activities

A screening ecological risk assessment (SERA) was completed for the Lab Area as part of the Final RI (CH2M HILL, 2004a). The SERA indicated that inorganics, semivolatile organic compounds (SVOCs) and some explosives in surface soil may impact the growth, survival, and/or reproduction of soil invertebrates and plants (refer to Table 6-14 in the Final RI Report). Therefore, these chemicals were selected as COPCs. No screening values were available for approximately one-third of the organic COPCs. Therefore, these COPCs were carried forward into Step 3A of the ERA process. In addition, there were several undetected organic chemicals with maximum detection limits in excess of screening values. These chemicals were carried forward as COPCs as well.

The ERA process was continued to Step 3A because there were maximum chemical concentrations that exceeded screening values in soil and food chain modeling indicated presumably unacceptable risks to every receptor species. Chemicals posing a presumably not unacceptable risk to soil invertebrates were not carried to Step 3A. For upper trophic receptors (i.e., food chain receptors), risks from all chemicals were recalculated in Step 3A using refined exposure assumptions.

Because potential risks to wetland receptors (i.e., water column invertebrates, amphibians, and omnivorous wetland mammals) will be addressed through a soil/sediment removal action and wetland restoration, further evaluation to refine the SERA risk estimates associated with sediment and surface water COPCs will not be conducted in the BERA

2.2.1 Results of Step 3A of the BERA

Because the SERA concluded that further evaluation was warranted, the initial step of the BERA (i.e., Step 3) was conducted. Step 3 consists of two phases: Step 3A and Step 3B. In Step 3A, risk estimates are recalculated on the basis of refined exposure assumptions, site-specific data, spatial distribution, and/or detailed literature review. Step 3B is the problem-formulation phase of the BERA. It involves evaluating the toxicity of site-related chemicals and refining the assessment endpoints and conceptual model developed in the SERA. Step 3B is presented in Section 3 of this BERA Work Plan.

Surface Soil Inorganics

The mean soil concentrations of aluminum, chromium, copper, cyanide, iron, lead, mercury, vanadium, and zinc at the Lab Area exceeded soil screening values. Of these, aluminum, cyanide, iron, and vanadium were present at concentrations consistent with NDWIH background (Tetra Tech NUS, 2002) as demonstrated below:

Inorganic	Surface Soil Lab Area Sample Mean Concentration (mg/kg) (*n* = 81)*	Surface Soil Background Mean Concentration (mg/kg) (*n* = 10 to 34)***	Ratio
Aluminum	5,515	7540	0.7
Chromium	18.9	13.6	1.4
Copper	126	6.5	19.4
Cyanide	0.32	0.42	0.8
Iron	11,304	13,000	0.9
Lead	999	17.9	55.8
Mercury	53.1 (*n* = 80)**	0.05	1,062
Vanadium	23.0	23.3	0.99
Zinc	445.8	20.2	18.1

mg/kg = milligrams per kilogram.

**n* = 81 since surface soil sample IS53SS59 was not included in ERA calculations.

***n* = 80 for mercury since surface soil sample IS53SS59 was not included in the ERA calculations and the mercury result for surface soil sample IS53SS42 was rejected.

****n* varies from 10 to 34 depending on the metal; values from 2002 background study (Tetra Tech NUS, 2002).

While the mean concentration of chromium in Lab Area surface soil is similar to mean NDWIH background levels, it is slightly elevated; however, it does fall within the NDWIH background concentration range of 3.5 mg/kg to 28.9 mg/kg. Furthermore, general background levels (i.e., worldwide) from the literature suggest soil-associated chromium typically exists in a range of 5 mg/kg to 250 mg/kg (Eisler, 1986), with a mean concentration reaching 37 mg/kg [National Oceanic and Atmospheric Administration (NOAA), 1999], and from 15 mg/kg to 100 mg/kg in Maryland (Dragun, 1991, as cited in Tetra Tech NUS, 2002). The chromium levels at the Lab Area are also within the range cited by Eisler (1986) and well below the NOAA (1999) mean background levels. While the benchmark used for screening chromium is much lower than site levels at 0.4 mg/kg, it is based on limited earthworm studies that incorporate chromium in its more bioavailable and soluble salt form (e.g., $K_2Cr_2O_7$ and $KCr(SO_4)_2$; Efroymson et al., 1997a). In the environment, chromium in soil is typically found in an unavailable form (Eisler, 1986). Therefore, it is expected that chromium poses minimal risks to soil invertebrates and terrestrial plants at the Lab Area.

Copper, lead, mercury, and zinc were detected in 95 percent or more of the soil samples collected at the Lab Area (*n* = 80 or 81). Mercury was ubiquitous in Lab Area soils, and its concentration was above 100 mg/kg in 12 percent of the surface soil samples. Mercury levels in excess of 100 mg/kg were detected in soils surrounding Building 103 (111 mg/kg to 637 mg/kg) and south of Building 102 (117 mg/kg). Buildings 102 and 103 are directly upgradient of the wetland area. A soil sample southwest of the wetlands and adjacent to Building 444 yielded mercury concentrations of 358 mg/kg. Two samples taken south of and adjacent to Building 600 yielded mercury concentrations of 120 mg/kg and 577 mg/kg, respectively. A mercury concentration of 962 mg/kg was measured in wetland area soils adjacent to the channel (in dry sediment sample IS53SD18).

The mean concentrations of copper, lead, mercury, and zinc exceeded soil screening values and were relatively ubiquitous at this site (i.e., each detected in 95 percent or more of all soil samples). Copper, lead, mercury, and zinc are substantially higher than facility and general environmental background levels. Therefore, these four inorganics may pose a risk to soil invertebrates and terrestrial plants and are retained as COCs for further evaluation.

Surface Soil Organics

1,1-Biphenyl, which did not have a screening value, was detected in 1 out of 20 soil samples at a concentration of 58 micrograms per kilogram (□g/kg). This level of biphenyl is lower than the soil screening value of 60 mg/kg for terrestrial plants (Efroymson et al., 1997b). In addition, the available screening values for all of the other phenolic compounds analyzed for in Lab Area soils were greater than or equal to 100 □g/kg. Biphenyl is expected to pose minimal risk to soil invertebrates and terrestrial plants because the level of biphenyl is approximately one-half the lowest phenolic screening value, the concentration does not exceed a terrestrial plant benchmark, the compound exhibited a low frequency of detection (i.e., detected in 1 out of 20 samples, or 5 percent), and it is expected to readily volatilize from surface soils.

Benzaldehyde was detected in 3 of 20 surface soil samples at a sample mean concentration of 0.2 mg/kg. Even though there was no soil screening value for benzaldehyde, toxicity studies from the literature suggest these levels may be too low to elicit significant effects to soil-associated biota. For example, the effective concentration that would affect 50 percent of the organisms, or the EC_{50}, for lettuce seed, *Lactuca sativa*, germination was 448 mg/kg following 14 days of exposure (Hulzebos et al., 1989). Furthermore, a 14-day No Observed Effect Concentration (NOEC) of 100 mg/kg has also been reported for *L. sativa* (Adema and Henzen, 2001). Based on these results and its infrequency of detection, benzaldehyde levels in the Lab Area surface soil are expected to pose minimal risk to soil-associated biota.

Although there were no screening values for bis(2-ethylhexyl)phthalate, butylbenzylphthalate, or di-n-octylphthalate, the total phthalate concentration in Lab Area surface soil can be evaluated by comparison to the total organic carbon (TOC)–adjusted Dutch soil quality standard screening value of 18,631 □g/kg (MHSPE, 1994). Summing the detection for each sample, concentrations ranged from 41 □g/kg to 26,046 □g/kg (Lab Area average TOC was approximately 6.23 percent). The total detected phthalate concentrations exceeded the TOC-adjusted screening value in only one sample [IS53SS01 had a hazard quotient (HQ) of 1.4]. Because the screening value of 18,631 □g/kg was exceeded in only one sample, and the magnitude of the exceedance was small (i.e., HQ of 1.4), phthalates in surface soil at the Lab Area are expected to pose minimal risks to soil invertebrates and terrestrial plants.

Several polynuclear aromatic hydrocarbons (PAHs) were detected relatively frequently in soil samples. The mean concentration of each individual PAH compound exceeded the screening value of 100 □g/kg. The screening value for each compound is a Biological Technical Assistance Group (BTAG) Region III value reportedly based on carcinogenic effects in mice treated with benzo(a)pyrene. Because the objective of this analysis is to evaluate potential effects to soil invertebrates (i.e., direct soil invertebrate exposure or potential exposures for upper trophic level receptors via ingestion of soil invertebrates), this screening value is not applicable to this evaluation. In addition, this screening value does

not account for site-specific TOC levels and the cumulative effect PAH compounds can elicit. In many cases, calculating a total PAH measure (i.e., sum of all individual compounds) allows for a more realistic screen of potential risks.
There is no Region III BTAG screening value for total PAHs, but the TOC-adjusted Dutch soil quality standard screening value for total PAHs is 12,915 □g/kg (MHSPE, 1994). This value was compared to the sum of the detected PAHs at each Lab Area sampling station (i.e., comparison to the screening values was made within each sampling station). There were 20 sampling stations for which PAH analysis was completed at this site.

The total PAH concentrations at 17 of the 20 sampling stations (i.e., 85 percent) were less than, or equal to, 5,950 □g/kg, which is less than one-half the TOC-adjusted screening value. Total PAH concentrations exceed the total PAH screening value at only three sampling stations (i.e., IS53SS14, IS53SS20, and IS53SS39). The HQs for stations IS53SS14, IS53SS20, and IS53SS39 are 1.1, 6.8, and 1.1, respectively. All three of these sampling stations are situated directly adjacent to facility buildings. Station IS53SS39 is adjacent to the northern side of Building 556, IS53SS20 is adjacent to the northern side of Building 595, and IS53SS14 is adjacent to the northern side of Building 108A (refer to Figure 2-1 of the RI).

The presence of PAHs at higher concentrations in these locations may be a result of isolated events (e.g., spill or dumping of waste oil) or ongoing processes (e.g., runoff from adjacent paved areas). Soils at other stations adjacent to these buildings were not analyzed for PAHs (i.e., 61 of the 81 soil samples were not analyzed for organics). Given the scattered nature of the elevated PAH concentrations at the site and the uncertainty surrounding their distribution, PAHs were retained as soil COCs.

Three other semivolatile organic chemicals—acetophenone, carbazole, and dibenzofuran—were also detected in Lab Area surface soil and were retained as COCs because there were no screening values for them. Acetophenone was detected in 4 of 20 samples at a mean concentration of 186 □g/kg, carbozole was detected in 5 of 20 samples at a mean concentration of 245 □g/kg, and dibenzofuran was detected in 2 of 20 samples at a mean concentration of 209 □g/kg. A recent study was published that reports the toxicity of two of these compounds to earthworms. Sverdrup et al. (2002) reported NOECs for the earthworm, *Eisenia veneta*, of 31 mg/kg for carbazole and 30 mg/kg for dibenzofuran. The maximum detected concentrations of these compounds were 1,600 mg/kg (carbazole) and 600 mg/kg (dibenzofuran). Thus, these compounds may pose a risk to soil invertebrates, although they were detected in only a few of the samples (carbazole: 5 of 20 stations, dibenzofuran: 2 of 20 stations). Not enough data are available to clearly define the spatial distribution of these SVOCs; however, as in the case for PAHs at the Lab Area, maximum concentrations of each were measured at IS53SS14 and IS53SS20 (two of the three locations where PAHs were elevated). This pattern suggests that SVOCs and PAHs may be co-located. Therefore, acetophenone, carbazole, and dibenzofuran were retained as COCs.

Four explosive compounds—2,4-dinitrotoluene; 2-amino-4,6-dinitrotoluene; HMX; and NC—were detected in Lab Area surface soil. There were no screening values for these explosive compounds. 2,4-Dinitrotoluene (2,4-DNT) was detected in 4 of 81 samples at a mean concentration of 0.34 mg/kg. 2-Amino-4,6-dinitrotoluene (2-ADNT) and HMX were each only detected in 1 of the 81 samples at concentrations of 2.1 mg/kg and 268.4 mg/kg, respectively. NC was detected in 22 of 81 surface soil samples at a mean concentration of 5 mg/kg, with a maximum concentration of 75 mg/kg.

Studies have shown that 80 mg/kg of 2-ADNT (almost 40 times higher than Lab Area surface soil) had no effect on yellow nutsedge or soil microbial processes following 42 days of exposure (Pennington, 1988). Studies with earthworms (i.e., *E. foetida*) exposed to HMX have suggested that relatively high levels of HMX would be required to result in significant toxicological effects. Fourteen days of exposure to as much as 500 mg/kg HMX resulted in no earthworm mortality, and less than an 18 percent reduction in weight (Phillips et al., 1993); this is almost twice the concentration detected in Lab Area surface soil. Likewise, reported levels resulting in effects for soil organisms exposed to 2,4-DNT are higher than Lab Area levels (UNEP, 2001). The effective concentration that would affect 10 percent of the organisms, or the EC_{10}, for springtail, *Folsomia candida*, exposed to 2,4-DNT for 33 days was 2.8 mg/kg. In addition, lettuce seeds, *Lactuca sativa*, exposed to 2,4-DNT for 14 days resulted in an EC_{50} of 4.9 mg/kg.

Based on available toxicity information and spatial distribution (i.e., frequency of detection ranges from one to five percent of the samples); 2,4-DNT; 2-ADNT; and HMX are likely to pose minimal risk to soil-associated biota and therefore will not be retained as COCs.

According to the U.S. Army Environmental Center (2001), NC is relatively nontoxic and readily undergoes biological degradation in soils. NC fines are typically composted in soils to render them inert. It has been shown that relatively high levels (540 mg/kg in sediment and 1,000 mg/L in water) had no effect on several invertebrates, fish, and algal species (Bentley et al., 1976; Sullivan et al., 1978). Because the levels in Lab Area soils are one or more orders of magnitude lower than those shown not to adversely impact sediment invertebrates, NC is expected to pose minimal risks to soil invertebrates and plants at the Lab Area.

2.2.1.1 Food Web Exposures

As presented in the table below, food chain exposure levels of mercury, lead, and zinc exceeded the Lowest Observed Adverse Effect Level (LOAEL)-based screening values (i.e., HQ greater than 1).

Ecological Receptor (Surrogate Species)	LOAEL-HQ		
	Lead	Mercury	Zinc
Mammalian terrestrial omnivore (white-footed mouse)	—	6.0	—
Avian terrestrial omnivore (American robin)	6.8	15.6	1.9

2.3 BERA Areas of Concern

The BERA will be focused on evaluation of the potential risk posed by the COCs that are present above background levels and are likely site-related.

Based on visual inspection, terrestrial vegetation is growing and shows no obvious signs of stress. Although the absence of gross chemically induced adverse effects on the physical structure of these environments does not preclude the potential for other, less-apparent effects, it demonstrates that the substrate will support a vegetative community. As such, plants were excluded from further consideration in the BERA.

The driver COCs identified for the Lab Area after Step 3A are shown in the table below.

Soil Invertebrates	Insectivorous Birds	Insectivorous Mammals
Copper	Lead	Mercury
Lead	Mercury	—
Mercury	Zinc	—
Zinc	—	—
Total PAHs	—	—
Acetophenone	—	—
Carbazole	—	—
Dibenzofuran	—	—

Available data indicate that inorganic contamination, while generally highest near facility buildings upgradient of the wetland, is distributed throughout much of the Lab Area. Although the distribution of organic COCs is not clearly defined, available data suggest that their occurrence may be a result of small, isolated releases.

A broad range of mercury concentrations were measured in the Lab Area surface soil (refer to Figure 3-5 of the RI). Most of the highest levels (i.e., 50 mg/kg to greater than 900 mg/kg at 12 of 81 sampling stations) were measured in samples taken adjacent to Buildings 101, 102, and 103. There were also eight sampling stations (close to the same buildings and upgradient of the wetland) at which mercury was measured at levels between 10 mg/kg and 50 mg/kg in soil. High mercury concentrations were also measured at two sampling stations (i.e., IS53SS48 and IS53SS49) off the southern side of Building 600. Unlike the sampling stations around Buildings 101, 102, and 103, the runoff from sampling locations IS53SS48 and IS53SS49 around Building 600 is not expected to flow eastward into the wetland. The topography shown on Figure 3-5 of the RI suggests that surface runoff from the south side of Building 600 may flow west along Evans Road. Although detected mercury concentrations elsewhere in the Lab Area have a lower range of 0.3 mg/kg to 10 mg/kg, they still exceeded the soil screening value of 0.1 mg/kg (Efroymson et al., 1997a).

Like mercury, the highest levels of lead were measured in surface soil samples collected near facility buildings directly north and northwest of the wetland. At six stations (i.e., IS53SS01, IS53SS03, IS53SS04, IS53SS25, IS53SS26, and IS53SS57), lead concentrations ranged from approximately 2,000 mg/kg to greater than 31,000 mg/kg (refer to Figure 3-4 of the RI). These high concentrations were primarily measured adjacent to Buildings 102, 103, 303, and 304. Levels of lead greater than 250 mg/kg (i.e., more than five times the screening value) were also detected near Buildings 101, 108, 108A, 502, 556, and 600, in addition to those buildings mentioned above. In total, lead levels adjacent to 10 buildings, 5 of which are directly upgradient of the wetland, exceed 250 mg/kg in Lab Area surface soil.

Zinc was also detected at elevated levels. The distribution of zinc was similar to that of lead and mercury. While selected as a COC, copper contamination was not as widespread or substantial as the other inorganic COCs. Levels at a small subset of sampling stations (e.g., IS53SS46 at 4,000 mg/kg and IS53SS74 at 964 mg/kg) strongly biased the mean concentration. Copper levels exceeded the soil screening value of 50 mg/kg (Efroymson et

al., 1997b) at approximately 30 percent of the stations, with the exceedances occurring near the same buildings where high lead and mercury concentrations were measured.

As discussed in Section 6.5.3 of the RI, the distribution of organic COCs is not clearly defined. Available data suggest that the occurrence of high levels of PAHs and other SVOCs does not follow the same pattern as has been observed for lead and mercury. The highest total PAH concentrations were detected at sampling locations on the north side of Buildings 600, 556, and 596. None of the highest mercury or lead concentrations were found on the north side of those buildings.

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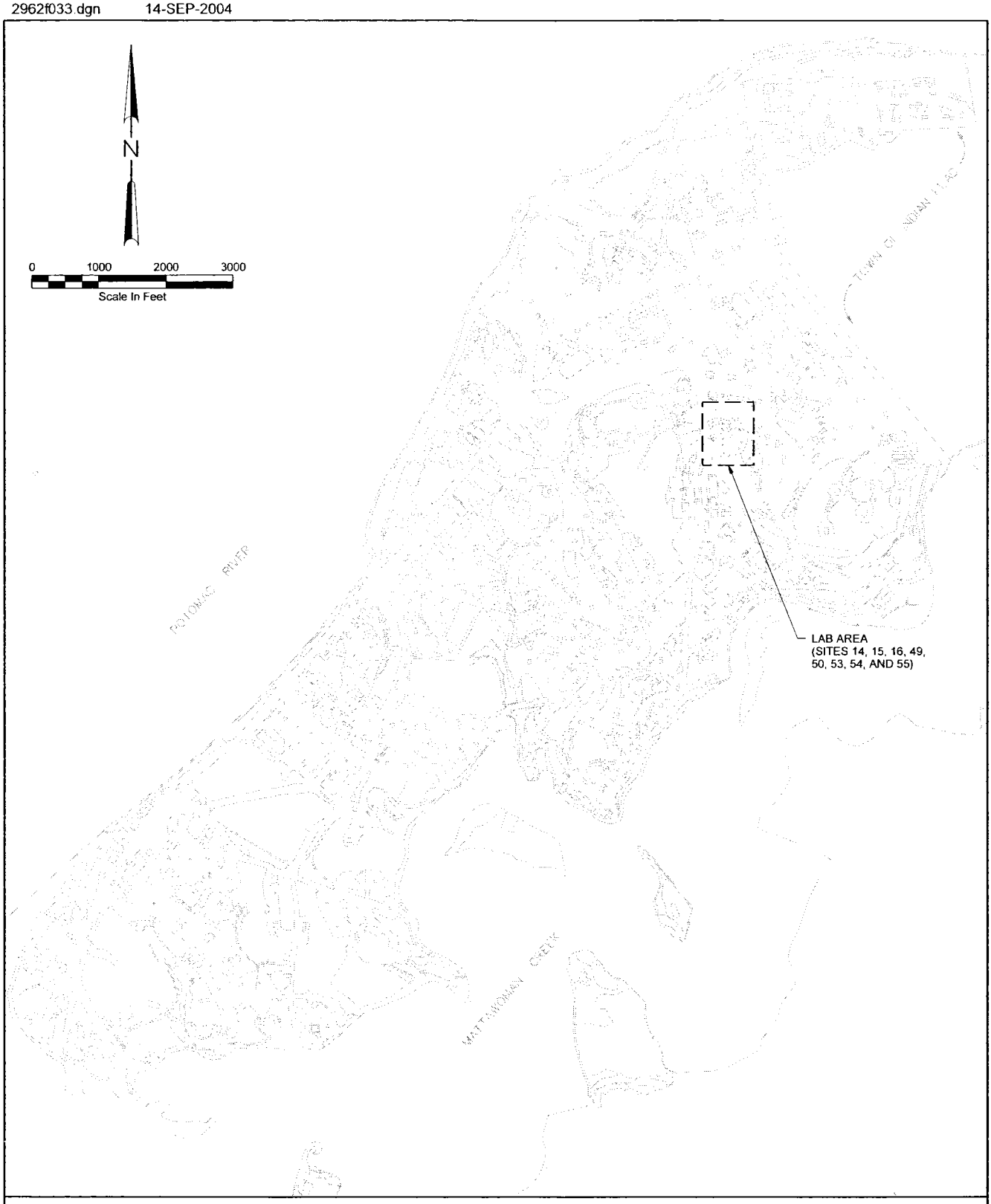

Figure 2-1
LOCATION OF LAB AREA
BERA WORK PLAN
NDWIH
INDIAN HEAD, MARYLAND

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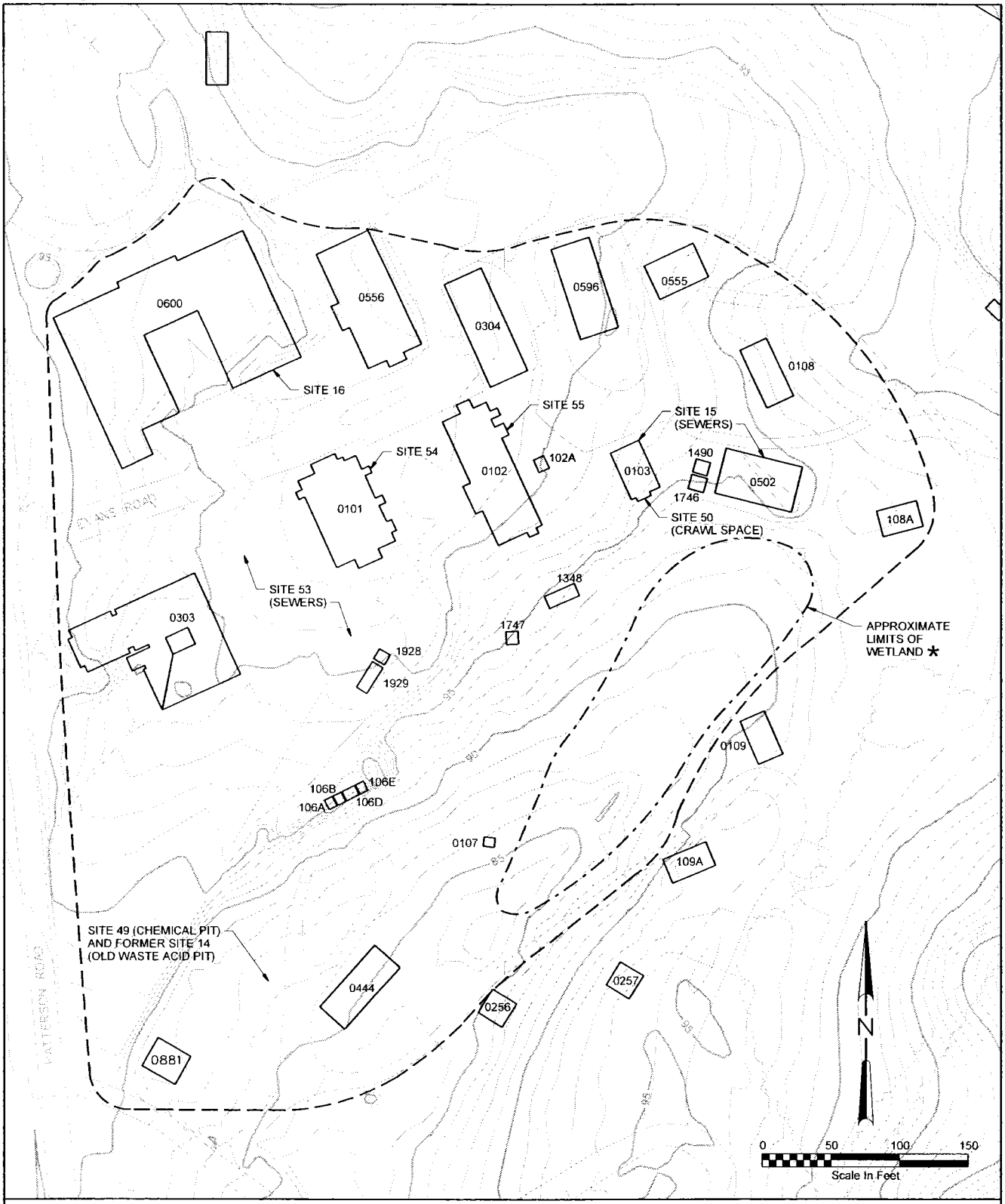


LEGEND

APPROXIMATE LIMITS OF EMERGENT WETLAND

LAB AREA BOUNDARY

* ESTIMATED LOCATION OF EMERGENT WETLAND IN MARCH 2001. WETLAND AREA CHANGES DEPENDING ON PRECIPITATION AND SATURATION, AS WELL AS THE PRESENCE OF UNDERGROUND LEAKING FRESHWATER PIPES (REFER TO SECTION 1.3.3 OF FINAL RI REPORT, CH2M HILL, JANUARY 2004).

Figure 2-2
LIMITS OF LAB AREA
BERA WORK PLAN
NDWIH
INDIAN HEAD, MARYLAND

CH2MHILL

SECTION 3

Baseline ERA Problem Formulation

The baseline ERA problem formulation is a revision of the previous problem formulation from the SERA and is focused on defining the issues associated with the COCs identified from the results of Step 3A. This revised problem formulation consists of an evaluation of the toxicity of the COCs and a refined conceptual model. The conceptual model includes a discussion of exposure pathways, assessment endpoints, and risk hypotheses.

3.1 Ecotoxicity Review

The classes of compounds from which COCs were selected include inorganics, semivolatile organics, and PAHs. Based on the Step 3A results, copper, lead, mercury, zinc, acetophenone, carbazole, dibenzofuran, and PAHs may pose a risk to the soil invertebrate community in the Lab Area. Additionally, lead, mercury, and zinc in the surface soil may pose a risk to upper trophic level receptors.

3.1.1 Inorganics

Copper, lead, mercury, and zinc were selected as COCs. In the Lab Area surface soil, each of these metals was identified as posing potential risks. A profile for each COC is provided below.

Copper

The bioavailability and toxicity of copper in soil is largely determined by the content of organic carbon (Streit and Jaggy, 1983). Acidic soil conditions also increase the availability of copper. Copper may bioaccumulate in earthworms (Czarnowska and Jopkiewicz, 1978; Ireland, 1979). In a study by Van Rhee (1977), it is suggested that the population density of earthworms is not related to the concentration of copper in soil; however, the concentration of copper in worm tissue was highly correlated to copper concentration in soil. Conversely, Ma (1987), Carter (1983), Beyer and Cromartie (1987), and Beyer et al., (1982) suggest that the correlation between the concentration of copper in soil and the concentration in worms is low.

High concentrations of copper in soil can adversely affect growth, reproduction and survivorship rates in earthworms. Earthworm rates of reproduction are generally more sensitive to the metal than mortality rates, and there is no evidence that any one genus of earthworms is less tolerant to copper, given the same set of conditions. After 6 weeks, a study reported that 2,000 parts per million (ppm) of copper decreased growth of *E. foetida* by 75 percent and cocoon production by 85 percent. No adverse affects were observed at a concentration of 1,000 ppm, however (Neuhauser et al., 1984). Spurgeon et al., (1994) kept adult *E. foetida* in $Cu(NO_3)_2$ contaminated soil at a pH of 6.3 for 8 weeks to test the survival and growth rates. LC_{50} was 555 ppm and EC_{50} for cocoon production was 53.3 ppm (1994). In experiments by Ma (1982), soil with 1,000ppm of $CuCl_2$ caused an 82 percent decrease in survival on *Lumbricus rubellus*. Streit and Jaggy (1983) studied the effect of soil organic

carbon on toxicity of $CuSO_4$ to the earthworm *Octolasium cyaneum*. The 14-day LC_{50} for soil with 3.2 percent organic carbon was 180ppm, 850ppm for soil with 14 percent organic carbon and 2500 ppm for soil with 43 percent organic carbon.

Lead

Due to the strong absorption of lead to soil organic matter, the bioavailability of lead is commonly limited. Organic compounds of lead are more bioavailable than inorganic lead. Compared to lead carbonate, lead sulfate is relatively soluble and likely to be more bioavailable. Lead can be bioaccumulated by plants and animals. The primary route of lead exposure to plants is through root uptake, though translocation to shoots is limited (Wallace et al., 1977). Biomagnification of lead has not been reported. Earthworms may bioaccumulate lead (Beyer, 1990; Roberts and Dorough, 1985).

Earthworm (*E. foetida*) growth and survival have been shown to be reduced following exposure to soil-associated lead (as $Pb(NO)_3)_2$) for 8 weeks (Spurgeon et al., 1994). In this study, the LC_{50} and EC_{50} (cocoon production) values for *E. foetida* were 3,760 and 1,940 mg/kg, respectively. The 14-day LC_{50} value for adult *E. foetida* exposed to lead (as $Pb(NO_3)$) in artificial soil was 5,941 mg/kg (Neuhauser et al., 1985). A 4-month study was carried out to determine the effects of lead to the earthworm (*Dendrobaena rubida*) at varying soil pH (Bengtsson et al., 1986). Following exposure to 500 mg/kg lead in soil with a pH of 4.5, the number of cocoons produced per worm, hatchlings per cocoon, and percent of cocoons hatched were reduced by 75, 100, and 100 percent, respectively. No adverse effects were noted with exposure to 100 mg/kg lead at the same pH. At pH 5.5 and 6.5, no adverse effects to the earthworms were observed.

Lead poisoning in birds is particularly well documented, but most lead poisoning in wild birds results from ingestion of lead pellets. In contrast, lead poisoning of birds, such as raptors, from biologically incorporated lead is considered unlikely. A 7-month study on the toxicological effects of lead ingestion in American kestrels found that an oral dose of 3.85 mg/kg/day did not cause any adverse reproductive effects (Sample et al., 1996); this dose was considered a chronic No Observed Adverse Effect Level (NOAEL). A chronic LOAEL of 38.5 mg/kg/day was estimated by multiplying the chronic NOAEL by an uncertainty factor of 10. A 12-week study with Japanese quail found that oral exposures to lead acetate in the diet did not have any adverse reproductive effects at doses of 1.13 mg/kg/day (chronic NOAEL) although adverse effects were observed at a dose of 11.3 mg/kg/day (chronic LOAEL; Sample et al., 1996).

Mercury

The majority of mercury in soil is bound in the organic soil horizon (Lindquist et al., 1991; Steinnes, 1990). Ionic forms of mercury are bound tightly to soil by forming complexes with organic matter in the upper soil horizon (Lindquist et al., 1991). Schuster (1991) found that under acidic conditions organic matter sorbs mercury, and Lodenius et al., (1987) found that solid organic matter in acidified soil decreases leaching of mercury by 300 percent. The dominant mercury species in soil are gaseous elemental mercury (Hg^o) and the mercuric ion (Hg^{2+}), and small amounts of monomethyl and dimethylmercury (CH_3Hg^+, $(CH_3)_2Hg$) (Revis et al., 1989; Steinnes, 1990; Schuster, 1991). The mercuric ion rarely occurs in the free

ionic form under natural conditions due to its strong complexing with organic matter (Steinnes, 1990).

Mercury is persistent in the environment and may cause significant effects on ecological receptors. The form of mercury most readily assimilated by biota is methylmercury. Once incorporated in tissues, methylmercury is very slow to depurate. The rate of bioaccumulation of methylmercury is species- and site-specific.

Survival and cocoon production in the earthworm *Octochaetus pattoni* were reduced by 65 and 40 percent, respectively, following exposure to 0.5 mg/kg mercury (Abbasi and Soni, 1983). However, exposure did not affect the number of juveniles produced. Studies have shown the effect of methylmercury to survivorship and segment regeneration in the earthworm (*E. foetida*) (Beyer et al., 1985). A concentration of 12.5 mg/kg mercury reduced survival by 21 percent, and the ability to regenerate excised segments was reduced by 69 percent. Furthermore, exposure to 2.5 mg/kg methylmercury had no effect (NOEC). A slug species (*Arion ater*) was used to determine the effect of mercury (as $HgCl_2$) on terrestrial mollusks (Marigomez et al., 1986). After 27 days of dietary exposure, *A. ater* displayed a 26 percent decrease in growth at 1,000 mg/kg mercury, while 300 mg/kg had no effect.

A three-generation study on the effects of mercury (administered orally as methyl mercury chloride) on the reproduction of rats indicated a LOAEL of 0.16 mg/kg/day because reduced pup viability was observed (Verschuuren et al., 1976). A chronic NOAEL of 0.032 mg/kg/day was determined because no adverse reproductive effects were observed at this level.

A 93-day study conducted on mink indicated that a dose of 1.8 ppm (administered orally as methyl mercury chloride) caused mortality, weight loss, and behavioral abnormalities (Wobeser et al., 1976). No adverse effects were observed at 1.1 ppm so this dose was considered a chronic NOAEL. These values were converted to a daily dose of 0.25 mg/kg/day (chronic LOAEL) and 0.15 mg/kg/day (chronic NOAEL).

A literature search was conducted on the toxicological effects of mercury ingestion to birds. A 1-year study conducted on Japanese quail indicated that an oral dose of 0.9 mg/kg/day (as mercuric chloride) caused reduced fertility and egg hatchability (Sample et al., 1996). This dose was considered a chronic LOAEL. No adverse reproductive effects were observed at a dose of 0.45 mg/kg/day. This dose was considered a chronic NOAEL.

Mallards fed methyl mercury during a 3-generation study showed significant reproductive effects (reduced egg and duckling production) at a daily dose 0.064 mg/kg/day (Sample et al., 1996). This dose was considered a chronic LOAEL. A chronic NOAEL of 0.0064 mg/kg/day was estimated by multiplying the chronic LOAEL by an uncertainty factor of 0.1.

Zinc

In the environment, the most common form of zinc is in the +2 oxidation state. Zinc is highly reactive in soils and can be adsorbed to clay minerals or metallic oxides (Sachdev et al., 1992). The active zinc species in the adsorbed state is the singly charged zinc hydroxide species (i.e., Zn(OH) +) (Sanders and El Kherbawy, 1987). This metal forms stable complexes with organic substances such as humic and fulvic acids. Metallic zinc is insoluble, but the

solubilities of zinc compounds range from insoluble (oxides, carbonates, phosphates, silicates) to extremely soluble (sulfates and chlorides) (Environment Canada, 1996).

Zinc solubility and mobility increases with decreasing soil pH. In soils with pH > 7.7, $Zn(OH)_2$ becomes the dominant form and solubility is very low. Zinc in a soluble form, such as zinc sulfate, is fairly mobile in most soils. However, relatively little zinc in most soils is in soluble form, and mobility is, therefore, limited by a slow rate of dissolution. Low pH (<7) and high ionic strength of the leaching solution favor desorption (EPA, 1987; Saeed and Fox, 1977).

E. foetida exposed to zinc (as zinc nitrate) exhibited lethal and sublethal (e.g., growth effects) effects (Spurgeon and Hopkin, 1995). Zinc exposure resulted in estimated LC_{50} and EC_{50} (growth) values of 216 and 400 mg/kg, respectively. Further studies evaluating the effects of zinc (as zinc acetate) in horse manure to *E. foetida*, showed reduced cocoon production (Malecki et al, 1982). Following an 8 week exposure, 2,000 mg/kg resulted in a 36 percent decrease in cocoon production, while 1,000 mg/kg had no effects. Following a 20-week exposure, 5,000 mg/kg resulted in a 53 percent reduction in cocoon production, while 2,500 mg/kg had no effect. Following zinc exposure in soil, the terrestrial isopod, *Porcellio scaber* exhibited prolonged molting (Drobne and Strus, 1996). The NOEL for *P. scaber* molting was 250 mg/kg.

Zinc toxicity to earthworms (*E. foetida*) was evaluated through studies with a range of artificial soils having varying organic content and pH (Spurgeon and Hopkin, 1996). In general, mortality increased as zinc concentrations increased, and a decrease in pH and organic matter (i.e., within the range tested) tended to decrease zinc toxicity. Depending on soil chemistry, the estimated EC_{50} values (cocoon production) for this study ranged from 136 to 592 mg/kg. Studies in which adult earthworms (*E. foetida*) were exposed to zinc (as $Zn(NO_3)$) in artificial soil (pH 6) were used to estimate LC_{50} values (Neuhauser et al., 1985). Following 14 days of exposure, an LC_{50} value of 662 mg/kg was calculated.

Reproduction in chickens exposed to zinc in the diet for 44 weeks was not adversely affected at a daily dose of 14.5 mg/kg/day but was adversely affected at 131 mg/kg/day. These doses are considered chronic NOAEL and LOAEL values, respectively (Sample et al., 1996).

3.1.2 Semivolatile Organics

Acetophenone

Information about the toxicity of acetophenone to soil invertebrates was not located in the literature.

Carbazole

Sverdrup et al., (2002) reported a No Observed Effect Concentration (NOEC), a growth EC_{10}, a growth EC_{50}, and an LC_{50} of 31 mg/kg, 35 mg/kg, 54 mg/kg, and 106 mg/kg, respectively, for the earthworm, *E. veneta*. A NOEC, a growth EC_{10}, a growth EC_{50}, and an LC_{50} of 17 mg/kg, 10 mg/kg, 35 mg/kg, and 2,500 mg/kg, respectively, were calculated for the collembolan, *F. fimetaria*, (Sverdrup et al., 2001). No other information about the toxicity of carbazole to soil invertebrates was located in the literature.

Dibenzofuran

Dibenzofuran is a polynuclear aromatic compound that may be found in coke dust, grate ash, fly ash, and flame soot. It has been listed as a pollutant of concern to EPA's Great Waters Program due to its persistence in the environment, potential to bioaccumulate, and toxicity to the environment. Sverdrup et al., (2002) reported a NOEC, a growth EC_{10}, a growth EC_{50}, and an LC_{50} of 30 mg/kg, 36 mg/kg, 61 mg/kg, and 78 mg/kg, respectively, for the earthworm, *E. veneta*. A NOEC, a growth EC_{10}, a growth EC_{50}, and an LC_{50} of 14 mg/kg, 19 mg/kg, 23 mg/kg, and 50 mg/kg, respectively, were calculated for the collembolan, *F. fimetaria*, (Sverdrup et al., 2001). No other information about the toxicity of dibenzofuran to soil invertebrates was located in the literature.

3.1.3 Polynuclear Aromatic Hydrocarbons

PAHs are virtually ubiquitous in nature, primarily as a result of natural processes such as forest fires, microbial synthesis, and volcanic activity. Anthropogenic sources of PAHs in the environment include high temperature combustion of organic materials typical of processes used in the steel industry, heating and power generation, and petroleum refining. They have been detected in animal and plant tissues, sediments, soils, air, surface water, drinking water, and groundwater.

PAHs of all sizes show little tendency for long-term bioaccumulation despite their high lipid solubility, probably because most PAHs are rapidly and extensively metabolized. Bioaccumulation is thus not considered an important fate in most multicellular organisms because it is usually a temporary process.

Information on PAH toxicity to soil invertebrates as a group is largely inferred from information on benzo(a)pyrene [B(a)P]. Salt-marsh caterpillars *(Estigmene aerea)* were observed to excrete most ingested B(a)P as fecal products. Approximately 50 percent of the 50 □g B(a)P fed to two caterpillars was excreted intact, while most of the remainder was degraded by hydroxylation and conjugation to highly polar derivatives (Lu et al., 1977). Isopods *(Porcellio saber)* fed leaf litter contaminated with 0–125 mg B(a)P/kg showed minimal mortality unrelated to B(a)P exposure. These results supported previous aquatic toxicity data that suggested a low acute toxicity for B(a)P (Neff, 1979; van Straalen and Verweij, 1991). Exposure to the highest level of B(a)P resulted in a significant increase in the rate of food assimilation and a significant decrease in the growth efficiency of male animals only, but the reasons for these changes were unclear. No other effects related to B(a)P ingestion were observed (van Straalen and Verweij 1991). Earthworms *(E. foetida)* exposed to deposits of B(a)P on filter paper for 48 h showed an LC_{50} >1,000 □g/cm^2 (Roberts and Dorough, 1984). Repeated dermal applications of a 0.5 percent solution of B(a)P to the earthworm *L. terrestris* resulted in hyperplasia and incipient tumors both at the application site and at other parts of the body after 8 weeks to 10 weeks of exposure (Montizaan et al., 1989). Two of 70 apple snails *(Ampullarius australis)* injected with a 1 percent B(a)P/oil solution developed papillomas in the area of the operculum (Krieg, 1970).

NOECs, growth EC_{10}s, growth EC_{50}s, and LC_{50}s for fluoranthene, fluorene, phenanthrene, and pyrene have been determined for the earthworm, *E. veneta* (Sverdrup et al., 2002) and the collembolan, *F. fimetaria*, (Sverdrup et al., 2001). *F. fimetaria* was more sensitive than *E. veneta*, with NOECs ranging from 13 mg/kg (pyrene) to 47 mg/kg (fluoranthene), as compared to 28 mg/kg (fluorene) to 98 mg/kg (fluoranthene) for *F. fimetaria*. LC50s were

also lower for the *F. fimetaria,* ranging from 41 mg/kg (phenanthrene) to 81 mg/kg (fluoranthene), as compared to 69 mg/kg (fluorene) to 416 mg/kg (fluoranthene) for *F. fimetaria.*

Toxicity information for total PAHs was not located in the literature. A Dutch soil quality standard screening value for total PAHs is available, and, using the site-specific TOC adjustment, was calculated at 12,915 μg/kg (MHSPE, 1994).

3.2 Conceptual Model

Information on the habitat features of the site, and the fate and transport of the COCs, are used to build the conceptual model (Figure 3-1). The conceptual model addresses complete exposure pathways, receptors, assessment endpoints, measurement endpoints, and risk hypotheses/questions. It has been revised to reflect the results of the SERA and Step 3A.

3.2.1 Exposure Pathways

Chemical sources at this site include historical chemical releases in the Lab Area. Receptors include soil invertebrates and terrestrial wildlife. Receptors may be exposed to chemicals via direct contact with abiotic media, ingestion, or trophic transfer through the foodchain.

The data gathered to date suggest that concentrations of copper, lead, mercury, zinc, acetophenone, carbazole, dibenzofuran and PAHs are elevated in surface soils at the Lab Area, possibly due to past disposal activities (mercury is known to be present from past disposal). The source of contamination is historic disposal of laboratory waste near the laboratory buildings. Receptors are terrestrial species that have contact with the soil (e.g., soil invertebrates, American robin, and white-footed mouse) or consume organisms that have direct contact with the soil (e.g., American robin, and white-footed mouse).

3.2.2 Assessment Endpoints

Refined assessment endpoints for the BERA are as follows:

Survival and growth of soil invertebrates— Soil invertebrates serve as a forage base for many terrestrial species. The soils at the site will support fewer birds and mammals if chemical concentrations are limiting the survival, growth, and reproduction of soil invertebrates.

Survival, growth, and reproduction of insectivorous birds—These receptors are third-order consumers and are thus more susceptible to bioaccumulative chemicals, especially those that have the potential to biomagnify. American robin (*Turdus migratorius*) was chosen to represent this endpoint. Robins live in a variety of habitats, including woodlands, swamps, suburbs, and parks. They forage on the ground in open areas, along edge habitats, or along the edges of streams. Robins forage for ground-dwelling invertebrates and search for fruit and foliage-dwelling insects in low tree branches (Malmborg and Willson, 1988). Since robins forage for soil invertebrates, their exposure to soil contamination would likely be significant.

Survival, growth, and reproduction of omnivorous terrestrial mammals—These receptors are second-order consumers and are thus more susceptible to bioaccumulative chemicals,

especially those that have the potential to biomagnify. The white-footed mouse (*Peromyscus leucopus*) was chosen to represent this endpoint. The white-footed mouse inhabits nearly all types of dry-land habitats within their range (Burt and Grossenheider, 1980). They are opportunistic feeders and eat seeds, arthropods, some green vegetation, roots, and fruit.

3.2.3 Risk Hypotheses

Risk hypotheses are questions about how assessment endpoints could be affected. Risk hypotheses clarify and articulate relationships that are possible through consideration of available data, information from the scientific literature, and the best professional judgement of risk assessors. The risk hypotheses/questions associated with the assessment endpoints are:

1. Are the concentrations of copper, lead, mercury, zinc, acetophenone, carbazole, dibenzofuran, and PAHs in surface soil at the Lab Area impairing the survival and growth of soil invertebrate communities to the extent that the prey base to support terrestrial insectivores has been adversely affected?
2. Is lead, mercury, or zinc in the surface soil at the Lab Area bioaccumulating in soil invertebrates to the extent that the growth, survival, or reproduction of omnivorous terrestrial mammals and insectivorous birds that forage at the site may be impaired?

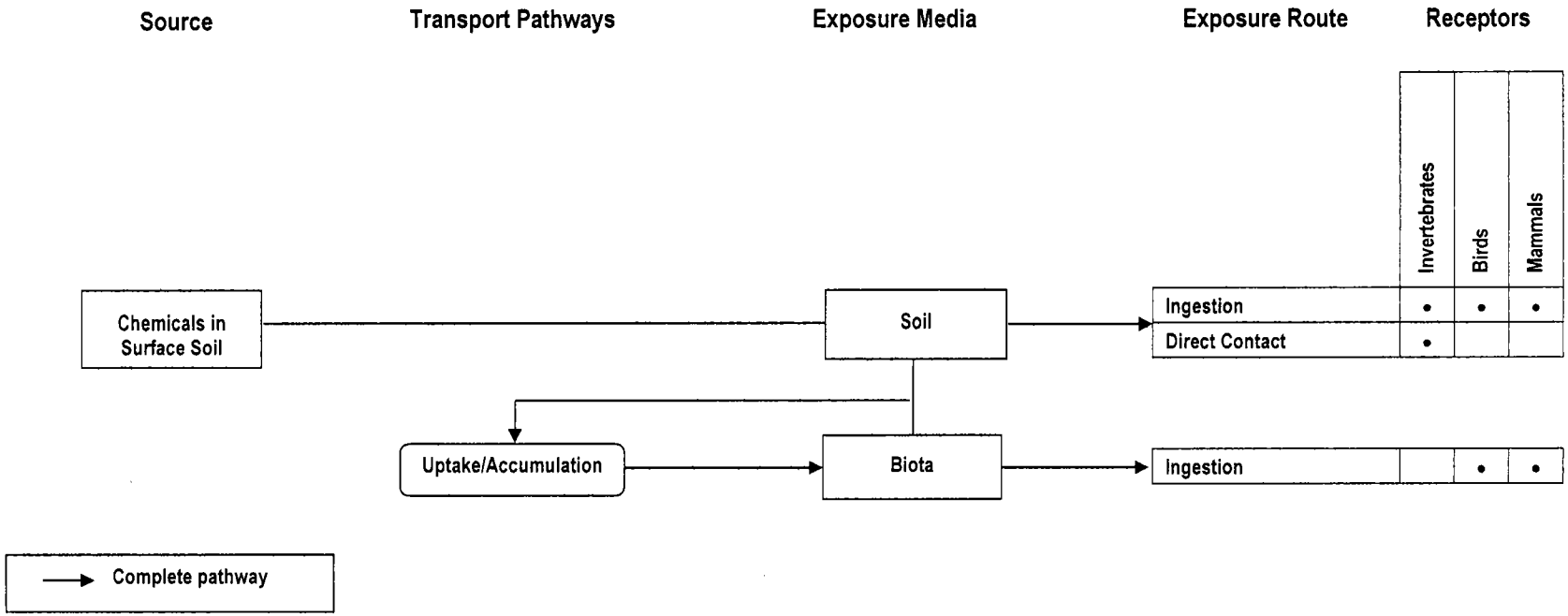


Figure 3-1
Ecological Conceptual Model
Lab Area BERA
NDWIH
Indian Head, Maryland

SECTION 4

Step 4: Study Design/Data Quality Objectives

Step 4 of the ERA establishes the measurement endpoints, the study design, and data quality objectives for the additional site investigations necessary to complete the ecological risk assessment (EPA, 1997). Another element of Step 4 is the sampling and analysis plan, which is provided in Section 5 of this document. The field sampling is designed to address areas identified as having the greatest potential risk and/or degree of uncertainty in earlier steps of the ERA process.

4.1 Measurement Endpoints

Measurement endpoints are measures of biological effects (e.g., laboratory toxicity test results) that are related to each respective assessment endpoint (EPA, 1997). For the areas of concern at the Lab Area, measurement endpoints associated with each assessment endpoint are defined as follows:

Assessment Endpoints	Measurement Endpoints
Survival and growth of soil invertebrate communities.	Comparison of results of 28-day soil toxicity tests (survival and growth) with the earthworm, *E. foetida*, using site and reference soils.
Survival, growth, and reproduction of birds and mammals that feed on soil invertebrates at the site.	Comparison of estimated exposure dose to toxicity reference value using site-specific bioaccumulation data obtained from lead, mercury, and zinc concentrations in earthworm tissue (from soil bioassays) to a reference LOAEL-based hazard quotient (HQ) of 1.0. As is stated in the Data Quality Objectives, the American robin (avian insectivore) and white-footed mouse (mammalian omnivore) are considered the surrogates for birds and mammals, respectively.

4.2 Study Design

This section presents the scope of the additional sampling planned for the Lab Area to address potential risks and uncertainties in the ERA. A detailed description of the proposed sampling activities and analyses is presented in Section 5 (Sampling and Analysis Plan).

4.2.1 Toxicity and Bioaccumulation Testing

To evaluate direct toxicity to soil invertebrates, 28-day laboratory toxicity tests will be conducted on split samples from soil sampling locations. At each location, sufficient sample volume to conduct the tests will be homogenized in the field prior to filling bottles for chemical and toxicological analysis. Soil samples will be analyzed for TAL metals, methylmercury, PAHs by selective ion monitoring (SIM), semivolatile organic compounds (SVOCs), pH, TOC, grain size, and percent moisture.

E. foetida (earthworm) will be used for soil toxicity testing. This organism was selected over *L. terrestris*, another earthworm species commonly used in soil toxicity testing, because there are more test data available on *E. foetida* than on *L. terrestris*.

The toxicity tests will provide information on earthworm survival and growth. Bioaccumulation will be determined at the end of the 28-day test period, when surviving worms will be submitted for tissue residue analysis (lead, total mercury, methylmercury, zinc, percent moisture, percent lipids). Chemical analyses of soil will support the toxicological analyses. A control will be run for each organism to ensure that the population used in the toxicity tests is healthy. Good health is demonstrated when the organism's performance meets or exceeds a designated threshold (e.g., 80 percent survival). The toxicity testing laboratory will determine the appropriate substrate for control testing.

4.2.2 Sample Locations

The spatial distribution of screening value exceedances for each risk-driving COC was evaluated to determine the locations for laboratory toxicity tests with site soils. Based on this evaluation, 10 surface soil sampling locations were identified for soil toxicity testing to characterize the potential risk to the soil invertebrate community in the vicinity of the Lab Area.

The 10 locations for soil toxicity testing were chosen to develop an exposure-response gradient. The locations were selected so that a range of COC concentrations, from the areas with the highest exceedances to areas with minimal to no screening value exceedances (except for mercury, which exceeded the screening value at every sampling location). The intent is to identify: (1) if there is a significant difference in survival or growth in site soils relative to reference and control soils, and (2) if there is a significant difference, can a toxic threshold concentration be identified for a given COC or mixture of COCs that can be used to aid in future risk management decisions for the site.

The surface soil locations selected for toxicity testing include the following (see also Figure 4-1):

RI Sample Location	Copper (Screening Value = 50 mg/kg)		Lead (Screening Value = 50 mg/kg)		Mercury (Screening Value = 50 mg/kg)		Zinc (Screening Value = 50 mg/kg)	
	Conc. (mg/kg)	Hazard Quotient	Conc. (mg/kg)	Hazard Quotient	Conc. (mg/kg)	Hazard Quotient	Conc. (mg/kg)	Hazard Quotient
IS53SS03	65.7	1.3	5860	117	637	6370	2550	51
IS53SS64	18.8	0.38	132	2.6	358	3580	97.3	1.95
IS53SS75	56.9	1.1	400	8.0	157	1570	347	6.94
IS53SS01	182	3.6	2330	47	111	1110	1670	33.4
IS53SS33	339	6.8	1190	24	52.3	523	1310	26.2
IS53SS26	156	3.1	21800	436	16.4	164	5770	115
IS53SS06	27.5	0.55	332	6.6	13.5	135	1280	25.6
IS53SS46	4000	80	254	5.1	5.8	58	604	12.1
IS53SS61	64.2	1.3	4.5	0.09	0.94	9.4	47.7	0.95
IS53SS18	7.6	0.15	18.9	0.38	0.76	7.6	38.9	0.78

4.2.3 Reference Samples

The response of organisms to reference soil will be statistically compared to the response of organisms exposed to site soil. This will ensure that only risk from site-related chemicals (at levels above basewide background) will be evaluated in the BERA. The response of organisms to control soil will also be compared with the response to reference soil in evaluating the results of the toxicity tests. Care will be taken to collect reference soil that has similar physical characteristics as the soil at the site. The similarities and differences between each reference area and the group of samples it is used for will be described and presented in the BERA report.

Reference soil will be collected from up to three of the sampling locations used in the Background Soil Investigation Report for NDWIH (Tetra Tech NUS, 2002). Soil from the reference site will be analyzed for the same parameters as the site samples, including bioaccumulation in the test organisms.

4.3 Data Quality Objectives

The DQO process provides a procedure for defining the criteria that a study design should satisfy. The steps of the DQO process are:

- Step 1 (State the Problem)
- Step 2 (Identify the Decision)
- Step 3 (Identify Inputs to the Decision)
- Step 4 (Define the Study Boundaries)
- Step 5 (Develop Decision Rules)
- Step 6 (Specify Limits on Decision Errors)
- Step 7 (Optimize the Design for Obtaining Data)

The steps of the DQO process for the Lab Area BERA investigation are described below.

Step 1. State the Problem

Various constituents were detected throughout the Lab Area in previous investigations, the more prominent being lead, mercury, zinc, SVOCs, and PAHs.

In general, the highest metal concentrations and the largest number of detections were encountered in samples collected around Buildings 102 and 103, and around other buildings in the eastern part of the Lab Area. This is likely due to storage and laboratory practices in these buildings and this portion of the site. Samples collected along the northwestern and northern portions of the site had among the lowest concentrations of metals, likely due to topography and laboratory density.

Inorganics in soil (particularly mercury) are of greatest ecological concern at the site, posing potential risks to soil invertebrates and upper trophic level receptors that have substantial direct contact with soils, or consume prey that have direct contact with soils. Food chain modeling suggests that lead and zinc may also pose risks to upper trophic level receptors through food chain exposures.

Although the distribution of organic COCs is not clearly defined, available data suggests that their occurrence may be a result of small, isolated releases. Relative to the inorganic contamination at the site, organic COCs are not expected to contribute significantly to ecological risk at the site.

Step 2. Identify the Decisions

Primary Question:

- What are the potential ecological risks related to COCs in surface soil in the Lab Area?

Secondary Questions:

- Are the chemical constituents in the surface soil toxic to the soil invertebrate community?
- Are bioaccumulative metals (primarily lead, mercury, and zinc) bioaccumulating in the prey (i.e., soil invertebrates) of birds and mammals at the site to the extent that unacceptable risks are present?

Step 3. Identify Inputs to the Decision

1. Analytical Chemistry Data
   - Copper, lead, mercury, zinc, acetophenone, carbazole, dibenzofuran, and PAHs pose potentially unacceptable ecological risk.
   - TOC, pH, and grain size.
2. Soil Toxicity Testing (risk to invertebrate communities)
   - Soil chemistry
   - Bulk soil toxicity
3. Tissue Analysis
   - Food web COC residues in earthworm tissue (obtained from bioassays)
4. Reference Site Data
   - Analytical chemistry data
   - Soil toxicity
   - Bioaccumulation
5. Ecological risk assessment models
   - Inorganic COC residues measured in earthworm tissue will be used to replace modeled values used in Step 3A to estimate risk to upper trophic level receptors, including American robin (avian insectivore) and white-footed mouse (mammalian omnivore). If results indicate no unacceptable risks for robin, then results will be used as evidence that no unacceptable risk to herbivorous birds exist as well, because herbivorous birds are lower in trophic level than are insectivorous birds.

Step 4. Define the Study Boundaries

1. Ten sample locations were selected in the Lab Area (refer to Figure 4-1) because they have a range of COC concentrations that are sufficient to produce a gradient of toxicity in the toxicity tests. The spatial coverage of the Lab Area by these locations is also considered adequate, but is of secondary importance to the goal of producing a dose-response relationship in the toxicity tests.

2. Sampling depth for soil will be 0–6 in., which approximates the biologically active zone (organic-rich soil/root layer is thin across the site). Consumption of soil invertebrates by higher-trophic-level consumers can facilitate movement of soil contamination through the food chain.

3. The soil reference areas are the sampling locations used in the Background Soil Investigation Report for NDWIH (Tetra Tech NUS, 2002).

Step 5. Develop Decision Rules

Soil Invertebrate Community. The following criteria will be used to weigh the results of the soil toxicity testing effort to assess potential risk to the soil invertebrate community.

Bulk Soil Toxicity. The growth and survival of test organisms in site soil will be statistically compared with the results of these parameters from reference and control soil. If significant (alpha, or α, level of 0.05) adverse effects are found, the soil will be considered toxic at a given station. If no significant adverse effects are found in any of the samples, then the soil will be considered nontoxic to the soil invertebrate community.

Soil Chemistry. If significant adverse effects are found in the site soil tests, then associations between biological and chemical data will be evaluated by examining the relationship between effects and COC concentrations and physical parameters (e.g., TOC, pH, and grain size). The ten sample locations were selected because they have a range of COC concentrations sufficient to produce a gradient of toxicity in the toxicity tests. A gradient of toxicity will produce dose-response relationships and no-effect levels for the COCs, which can be used to support development of clean-up goals for the site, if warranted. A combination of statistical and observational methods will be used to identify chemicals in bioassay media potentially responsible for observed toxicity. Chemicals potentially contributing to toxicity will be identified using simple correlation and multiple regression analyses and visual evaluation of single-chemical dose-response scatter plots over multiple chemicals and in relation to literature-based single chemical toxicity data. Once a chemical is determined to be potentially contributing to toxicity (or cannot be excluded as not contributing to toxicity), dose-response analyses using linear or nonlinear regression methods will be used to develop a model from which effect concentrations could be developed.

Upper Trophic Level Receptors. The following criteria will be used to weigh the results of the sampling effort to assess potential risk to upper trophic level receptors that may forage on soil invertebrates at the Lab Area.

Invertebrate Tissue Analysis. The COCs measured in the earthworm tissue from the bulk soil toxicity tests will be used to model exposure to insectivorous birds and omnivorous

mammals. Unacceptable risk will be constituted by exceedance of LOAEL-based reference toxicity values for these receptors. The conclusions for insectivorous birds will be considered applicable for herbivorous birds, as exposure doses of the COCs are likely to be much lower for herbivorous species than for insectivorous species. If unacceptable risks are identified for these receptors, then the site-specific bioaccumulation data derived from the tests will be used to develop site-specific bioaccumulation factors, which will be used to derive PRGs for the site if warranted.

Step 6. Evaluate Decision Errors

The intent of this data collection effort is to reduce uncertainty in the risk estimates arrived at after the conclusion of Step 3A. The results of this effort will determine the baseline ecological risk posed by COCs in the surface soil at the Lab Area.

Baseline Decision Rule Errors:

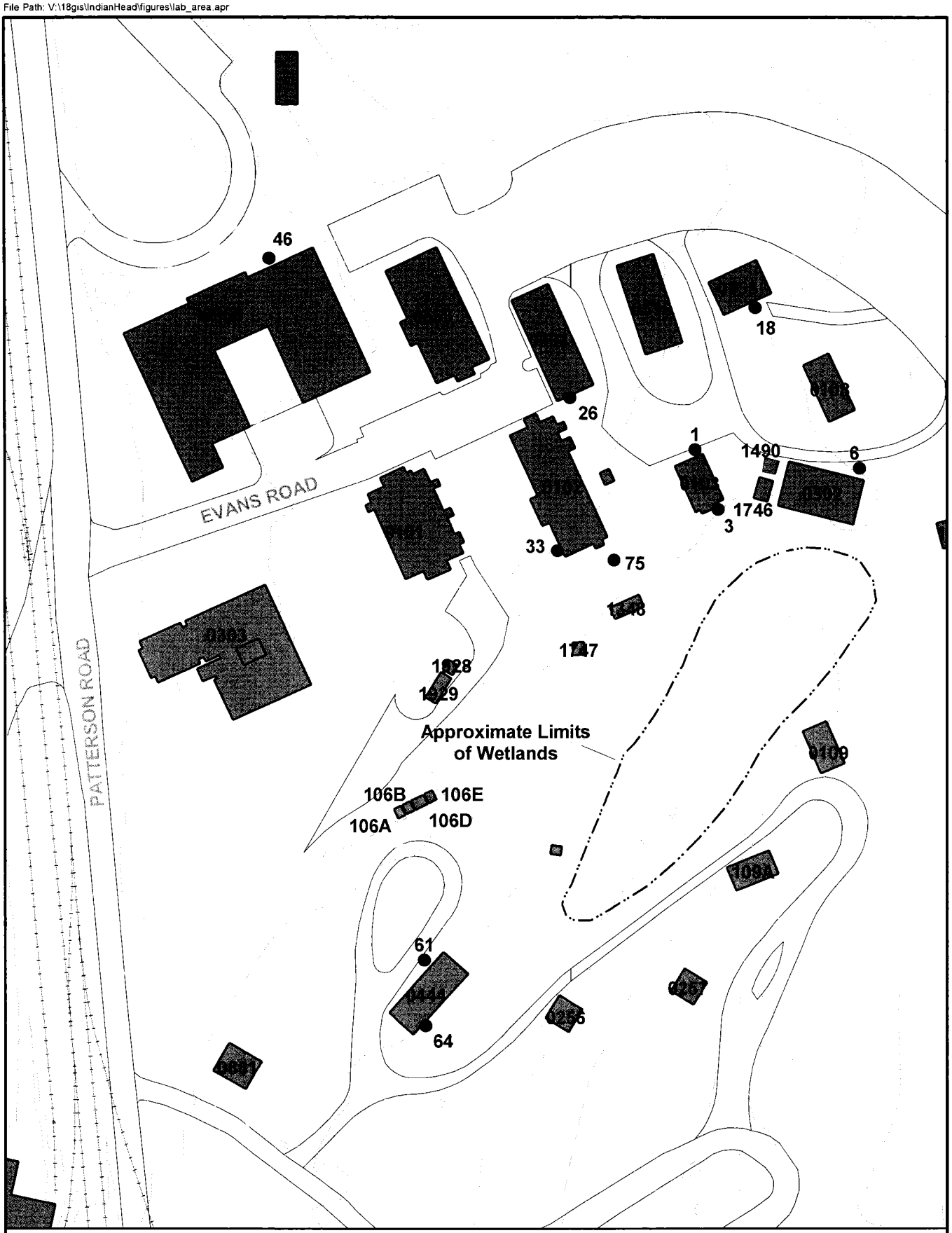
1. Deciding that the COCs in the surface soil at the Lab Area are toxic to ecological receptors and potentially causing harm when, in fact, they are not toxic to ecological receptors. The consequence of making the error is deciding to proceed with remediation when there is no unacceptable risk. The level of significance that will be used to evaluate the data (i.e., the probability of making this Type I error) is $\alpha = 0.05$.

2. Deciding that the COCs in the surface soil at the Lab Area are not toxic to ecological receptor when, in fact, they are toxic and are potentially causing harm to ecological receptors. The consequence of this error is failing to proceed with remediation when an unacceptable risk is present. The probability of making this Type II error has been lessened by setting $\alpha = 0.05$, because the smaller the level of significance chosen for the analysis, the larger the probability of making a Type II error.

Step 7. Optimize the Design for Obtaining Data

The study design for obtaining the data to reduce the uncertainties surrounding the SERA risk conclusions at the Lab Area was described above. The uncertainty in the risk to the soil invertebrate community will be reduced through the results of the toxicity testing, which will provide site-specific, effects-based data. The uncertainty in the risk estimates for upper trophic level receptors will be greatly reduced by developing site-specific bioaccumulation data from the COC residues in earthworms used in the bulk soil toxicity tests. These data will provide more accurate estimates of the bioavailability and bioaccumulation potential of COCs in the soils, rather than relying on bioaccumulation factors from the literature. Therefore, the outcome of this effort should provide a realistic baseline estimate of potential ecological risk to upper trophic level receptors that forage at the site. The concentration gradient approach was proposed to ensure that the results of this assessment could be used to develop cleanup levels, if warranted, and to provide reliable site-specific toxicity values that can be utilized at other locations at Indian Head. Necessary detection limits for metals in the media at the site are based on ecological screening criteria. Detection limits should remain below the chemical-specific screening criteria for metals and PAHs.

File Path: V:\18gis\IndianHead\figures\lab_area.apr



LEGEND

● SURFACE SOI L SAMPLE LOCATIONS
(TRUNCATED SAMPLE IDs FROM PREVIOUS SAMPLING
SAMPLE ID FORMAT IS53SS##0001)

N

0 50 100 Feet

Figure 4-1
Lab Area Surface Soil
Sample Locations
BERA Work Plan
NDWIH
Indian Head, Maryland

CH2MHILL

SECTION 5

Sampling and Analysis Plan

The Sampling and Analysis Plan is comprised of two components: the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP). The FSP provides detailed descriptions of the sampling activities and procedures that will be used to meet the objectives of this work plan. The QAPP provides a description of the quality control procedures that will be used to ensure that the data collected meet the DQOs of this work plan.

5.1 Field Sampling Plan

5.1.1 Surface Soil

Surface soil will be collected from the 10 locations shown on Figure 4-1 and as described in Section 4.2.2. At each location, the sample will be collected from 0 to 6 in. below ground surface with a decontaminated trowel or shovel. The sample will be placed in a decontaminated stainless steel bowl and homogenized (i.e., mixed for consistency) with a stainless steel trowel. Approximately 8 L of sample will be placed in a sample jar for off-site laboratory analysis. To prevent cross contamination, sampling equipment (i.e., trowel, shovel, and mixing bowl) will be decontaminated between sampling locations.

The surface soil samples will be submitted for toxicity testing and chemical analysis. The soil chemistry sample containers will be filled and the remainder of the soil will be placed in the sample containers provided by the bioassay laboratory.

A 28-day soil toxicity test with the earthworm *E. foetida* will be conducted for each sample. The chemistry samples will be analyzed for TAL metals, PAHs (SIM method), SVOCs, pH, total organic carbon (TOC), and grain size (by sieve analysis). At the conclusion of the 28-day tests, the earthworm tissue from each test will be analyzed for lead, mercury, zinc, percent lipids, and percent moisture to provide site-specific bioaccumulation data for these metals.

5.1.2 Reference Soil

The soil reference site(s) will likely be one or more of the sampling locations used in the Background Soil Investigation Report for NDWIH (Tetra Tech NUS, 2002). If the physical characteristics of the soil at these locations are not consistent with those at the Lab Area, then additional locations will be investigated as potential reference sites.

The reference sediment sample will be analyzed for the same suite of parameters as the site samples.

Samples to be collected for the following analyses:

Summary of Samples to be Submitted to the Laboratory

Matrix	Laboratory Parameter	Samples	Field Duplicates	Field Blanks	Equipment Blanks	Matrix Spikes	Total Samples
Soil	TAL metals	13	2	1	2	1/1	20
	PAHs (SIM)	13	2	1	2	1/1	20
	SVOCs	13	2	1	2	1/1	20
	TOC	13	2				15
	pH	13	2				15
	Grain size (sieve)	13					13
Tissue	TAL metals	13				1/1	15
Toxicity Testing							
Soil	Toxicity Test	13					13

Notes: One field blank will be collected during the sampling event. An equipment blank will be collected for each sampling day and medium. Matrix spikes are two samples, one matrix spike and one matrix spike duplicate.

Analytical methods to be used are as follows:

Analytical Methods

Analysis	Methodology
TAL Metals	U.S. EPA CLP Inorganics SOW ILM04
PAHs	SW-846 8270 SIM PAH
SVOCs	SW-846 8270
TOC	Lloyd Kahn Method
pH	SW-846 Method 9045
Grain Size	ASTM D-422 (sieve analysis, include graph, no hydrometer)
28-day Toxicity Test	ASTM E1676-97 (ASTM, 2001); EPA/600/3-88/029 (EPA, 1989)

All sample containers will be provided by the laboratory subcontractor in a clean and, if appropriate, pre-preserved state, as defined in the Master Plans for Installation Restoration Program Environmental Investigations Naval District Washington Indian Head (Tetra Tech NUS, 2004) (herein referred to as Master Plans). Laboratory-grade contaminant-free water will be provided by the laboratory subcontractor for equipment blanks. Pre-prepared trip blanks will be provided by the laboratory subcontractor. Analytical results will be delivered in both hard copy and electronic data packages using standard 28-day turnaround time.

5.2 Quality Assurance Project Plan (QAPP)

Quality assurance procedures are described in the Master QAPP of the Master Plans (Tetra Tech NUS, 2004). Quality control (QC) samples will be used to verify the accuracy and precision of the chemical data generated during the investigation. When data are suspect because a QC sample is outside of a laboratory's established control limits, the data user will

be notified through the laboratory report's case narrative and the data validator's report. No field QC samples will be collected for the laboratory toxicity tests. Analytical results will be validated by an independent data validator using U.S. Environmental Protection Agency Region III modifications to the National Functional Guidelines, as described in the Master Plans (Tetra Tech NUS, 2004).

Field QC samples will be collected as follows for analytical samples:

Type of QC Sample	Frequency Collected
Field Duplicate	One per matrix for each group of up to 10 samples
Field Blank	One for the event
Equipment Blank	One every day if equipment is decontaminated for reuse
Matrix Spike/Matrix Spike Duplicate	One pair for each group of up to 20 samples per media sent to a single laboratory

5.2.1 Sample Identification System

Each sample will be designated by an alphanumeric code that identifies the site and matrix sampled and contains a sequential sample number. Site-specific procedures are elaborated below.

The following is a general guide for sample identification:

First Segment of Sample Number	Second Segment of Sample Number	Third Segment of Sample Number		
Naval Installation Abbreviation	Site Number	Sample Type	Sample Location	Additional Qualifiers (sample depth, date)
A	AAA	AA	NN	NNNN

Symbol Definition:

"A" = Alphabetic
"N" = Numeric

Site Abbreviation:

A = One letter abbreviation identifying the Naval Installation where the sample was collected (i.e., Indian Head = I)

Site Number:

ANN = Three letters identifying the site on the facility where the sample was collected (i.e., SLB = Site Lab Area)

Sample Type:

TX = Toxicity Test Sample
SS = Surface Soil
EB = Equipment Blank
FB = Field Blank

Sample Location:

MM = QC Samples — two-digit month of sampling event
NN = Primary Samples — two-digit number indicating sample location

Additional Qualifiers:

BDED = Surface Soil Samples — two-digit begin depth and two-digit end depth rounded up to nearest foot (i.e., 2'-2' 6" = 0203)

DDYY = QC Samples — two-digit date and two-digit year of sampling event

An example of this numbering approach is:

ISLBSS040001 The fourth surface soil sample collected from 0 foot to 1 foot at the Lab Area

An example of this numbering approach for QA/QC samples is:

ISLBEB071504 Equipment blank collected at the Lab Area on July 15, 2004

Field duplicates will be "blind duplicates," and thus labeled in the same manner as regular samples. Their locations and corresponding sample numbers will be recorded in the log book.

5.2.2 Sample Packaging and Shipping

Samples will be tightly packed in a cooler with bubble wrap packaging material and ice as a preservative. The samples will be either picked up at the site by the analytical laboratory or shipped to the laboratory via overnight courier. The field team leader is responsible for completion of the following forms:

- Sample labels and Chain of Custody seals;
- Chain of Custody forms; and
- Appropriate labels and forms required for shipment.

Custody of the samples will be maintained and documented at all times. Chain-of-Custody will begin with the collection of the samples in the field and will continue through the analysis of the sample at the analytical laboratory.

5.3 Health and Safety

An addendum to CH2M HILL's Master Health and Safety Plan for the Lab Area (CH2M HILL, 2004b) will be prepared for this field effort. The field team will conduct all fieldwork in accordance with the plan and addendum as well as the Master Field Sampling Plan of the Master Plans.

5.4 Investigation-Derived Waste Management

Small amounts of liquid investigation-derived waste (IDW) will be generated during decontamination of sampling equipment. Disposable sampling equipment will be used wherever possible to minimize the generation of decontamination rinse water. All IDW and personal protective equipment used during the sampling will be disposed of per the Master Field Sampling Plan of the Master Plans (Tetra Tech NUS, 2004).

5.5 Project Reporting

The methods, results, analyses, and risk characterization will be reported in the draft BERA. The report will evaluate the potential risk to ecological receptor populations at the Lab Area. If a risk exists, the report will identify the spatial extent that should be considered for remedial action by the Indian Head Installation Restoration Team.

SECTION 6

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